

Judging the intensity of emotional expression in faces: the effects of **colored** tints on individuals with autism spectrum disorder

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Page lay abstract:

Individuals with autism spectrum disorder (ASD) display impairments in social interaction as well as difficulties processing sensory information, which may explain, in part, impairments in the perception of emotion in facial expressions. Parallels have recently been drawn between the symptoms of visual stress and the sensory difficulties experienced by individuals with ASD. Visual stress refers to the experience of discomfort and perceptual distortions (particularly from text), and can be reduced with the use of colored overlays/tints when reading. Sixteen children with ASD and a typically developing (TD) comparison group were assessed for their ability to discriminate correctly between the emotional intensities expressed in pairs of faces. Faces were presented on a computer screen that was tinted either gray or with a color previously chosen by the participant as comfortable. Judgments of emotional intensity improved with the addition of the individual preferred colored tint in the ASD group but not in the control group. Children with ASD appear to have atypical face processing that may be related to visual stress and difficulties processing sensory information.

Scientific Abstract

Individuals with autism spectrum disorder (ASD) often show atypical processing of facial expressions, which may result from visual stress. In the current study, children with ASD and matched controls judged which member of a pair of faces displayed the more intense emotion. Both faces showed anger, disgust, fear, happiness, sadness or surprise but to different degrees. Faces were presented on a monitor that was tinted either gray or with a color previously selected by the participant individually as improving the clarity of text. Judgments of emotional intensity improved significantly with the addition of the preferred colored tint in the ASD group but not in controls, a result consistent with a link between visual stress and impairments in processing facial expressions in individuals with ASD.

Keywords: facial expressions; sensory; autism spectrum disorder; tints; overlays; visual stress

Individuals with autism spectrum disorder (ASD) often display impairments in social interaction as well as heightened or diminished sensory processing (Stevenson et al., 2014, also see Harms, et al., 2010 and Simmons et al., 2009 for recent reviews). Impairments in social interaction may include a preference for objects over people (Hobson, et al., 1988; Klin et al., 1999; Langdell, 1978; Lord, et al., 1994; Osterling & Dawson, 1994) as well as atypical processing of facial expressions (Behrmann et al., 2006; Greimel et al., 2014; Kliemann et al., 2010; Uljarevic & Hamilton, 2012). However, the link between visual sensory processing and social communication difficulties in ASD has received comparatively little study (see Ludlow, et al., 2012; Harms, et al., 2010; Philip et al., 2010; Uljarevic & Hamilton, 2012).

Individuals with ASD have also been reported to show differences in visual acuity compared to typically developing (TD) controls, measured using Gabor and Gaussian patches (Bertone et al., 2005; Maguire, 2014; Sanchez-Marín & Padilla-Medina, 2008; Spencer & O'Brien, 2006), as well as abnormal color processing (Franklin et al., 2008) and color memory (Heaton, et al., 2008). Some individuals with ASD also report experiencing headaches and nausea when viewing certain colors (Ludlow & Wilkins, 2009; Williams, 1999). Recent research has drawn parallels between the symptoms reported by individuals who suffer from visual stress and the sensory difficulties experienced by individuals with ASD (Wilkins, 2012). Visual stress (also referred to as Meares-Irlen syndrome) refers to visual discomfort and distortions, particularly when viewing text, including blurring or apparent movement, or colors around letters (Wilkins & Nimmo-Smith, 1984; 1987). Some individuals with ASD report these symptoms and may also be diagnosed with visual stress (e.g. Ludlow & Wilkins, 2009; Ludlow, et al., 2008). People show consistency with respect to the images that they judge to be uncomfortable, and this discomfort can be predicted from an image's Fourier amplitude spectrum. This applies to images ranging from photographs of everyday scenes, to modern art and geometric arrays (Fernandez & Wilkins 2008). Images are generally rated as uncomfortable to view if their characteristics depart from those that occur in natural images. For example, they are less comfortable to view if the slope of the Fourier amplitude spectrum differs from  $1/f$  (Juricevic et al., 2010) and if the chromatic contrast is unnaturally high, regardless of the particular chromaticities within a large gamut (Haigh et al., 2013). For those individuals who experience visual stress when reading text, Wilkins (2003) showed that transparent colored overlays could reduce perceptual distortions leading to alleviation of symptoms and improved reading speed.

Individuals with ASD are four times more likely to benefit from colored overlays than controls (Ludlow et al., 2008). However, the evidence for the improvements in reading speed remains controversial (Albon et al., 2008; Galuschka, & Schulte-Körne, 2014). The improvements have been assessed in terms of the rate with which randomly ordered words are read aloud. Henderson et al., (2014) have argued that this is an unrealistic measure of reading speed. A recent systematic review concludes that “[sic]given ... *contradictory findings, a precautionary, prudent position ... on the use of colored overlay seems desirable, especially in clinical or educative contexts, but from another side, given that some evidence that the colored overlays work exists, concluding that colored overlays proved not worth in allaying reading problems is premature and, possibly, incorrect.*” Uccula, Enna and Mulatti (2014, p. 3-4).

Individuals who experience visual stress may show a large cortical haemodynamic response to a visual stimulus that they find uncomfortable to look at. Increased cortical hyperexcitability, measured by increased blood oxygenated level-dependent (BOLD) response, has been found in both individuals who experience migraines (Huang, et al., 2003) and those who experience visual distortions without migraines (Chouinard et al., 2012) when viewing visually disturbing stimuli. The abnormal cortical reaction may reflect inefficient neuronal processing (Wilkins & Hibbard, 2014).

The cortical hyperexcitability account is not the only explanation for visual stress. The magnocellular deficit (Chase et al., 2003; Chouinard, Zhou, Hrybowski, Kim, & Cummine, 2012) and noise exclusion deficit theories (see Facoetti, et al., 2010 and Sperling et al., 2005 for examples) also provide explanations for visual stress. Magnocellular layers form part of a pathway that leads from the retina to the primary visual cortex (Stein, 2003). A primary function of the magnocellular pathway is to process rapid changes in the visual field. Post mortem evidence of abnormal growth of the magnocellular pathway in individuals with dyslexia has been used to support the magnocellular deficit as the underlying mechanism for visual stress in dyslexia. Stein (2003; Stein & Kapoula, 2012) proposes that abnormalities in the magnocellular pathways would impair binocular coordination, resulting in symptoms of visual stress such as words jumping and moving on the page. Deficits in magnocellular function have also been observed in ASD, although data are equivocal (see Greenaway et al., 2013 for a recent summary). The contrasting results may reflect that magnocellular deficits are only common to a proportion of individuals with ASD (e.g. Greenaway et al., 2013).

In contrast, noise exclusion deficit theories propose that any difficulties for individuals with dyslexia when reading are due to deficits in excluding noise from the visual world (Sperling et al., 2005). Irrelevant stimuli lead an individual to ignore the important information, such as the text on a page (Ruffino et al., 2010). This difficulty may not be specific to text and may cause processing difficulties across domains (Facoetti, et al., 2010 and Sperling et al., 2005). It has been proposed that individuals with ASD experience levels or neural noise that are either atypically high (Rubenstein & Merzenich, 2003; Simmons et al., 2007, 2009) or low (Davis & Plaisted-Grant, 2014).

From an alternative perspective, the Enhanced Perceptual Functioning model (EPF; Mottron & Burack, 2001; Mottron et al., 2006a) asserts that aspects of low level processing are enhanced in ASD and that they are relatively immune to top-down influences. Atypical visual perceptual experiences are argued to associate with unusual looking behaviours in young children with ASD (Mottron et al., 2007). It is conceivable that fundamental perceptual atypicalities have downstream effects on higher order social cognitive processing, either directly (atypical perceptual input) or indirectly (e.g. atypical attentional focus).

Typical individuals who suffer from visual stress have also been shown to have impaired processing of facial expression: Robinson and Whiting (2003) and Whiting and Robinson (2001) found that typical individuals suffering from visual stress had impaired recognition of facial expressions compared to controls, which improved with the use of colored overlays. The benefits of colored overlays have also been documented for complex emotions. In a paper version of the “Reading the Mind in the Eyes” task (Baron-Cohen & Cross, 1992), Ludlow, et al., (2012) demonstrated an improvement in the classification of facial emotional expressions from the eye area, in individuals with ASD, using colored overlays. A single case study of an individual with ASD showed an improvement in social and communication abilities when individually tinted colored glasses were worn (Ludlow & Wilkins, 2009). These findings, involving not only textual but social stimuli, are consistent with a link between visual stress and impairments in social and communication abilities.

The present experiment extended previous research by examining whether a colored tint would improve judgments of relative emotional intensity rather than simply the categorization of emotions. The discrimination of emotional intensity was examined in the light of previous research, which has documented that individuals with ASD have difficulty judging the intensity of some emotional expressions and this may lead to social and communication

difficulties in day-to-day life (Rump et al., 2009; Rutherford & McIntosh, 2007; Rutherford & Towns, 2008). In contrast to Ludlow et al., (2008), who used images showing only the eye region of the face (Baron-Cohen & Cross, 1992), we used the whole face to simulate a more realistic social-emotional scene. Intensity judgments may require more holistic processing than categorization but do not require access to verbal labels for emotion categories, so even individuals with language impairments could be tested (Harms et al., 2010). We also, used whole faces because different areas of the face are diagnostic of different facial expressions (Roberson, et al., 2010; Roberson et al., 2012; Smith et al., 2005) and we wanted to investigate the generality of the effects. We compared 16 colored tints to a neutral gray tint to rule out the possibility that improvements in performance were due to reduced contrast between face and background that would have occurred with any tint, rather than one specifically selected as improving clarity (Ludlow et al., 2008).

In contrast to previous research, which adopted the use of 10 colored overlays in the Intuitive Overlays task, we opted for 16 colored tints. The use of 16 instead of 10 colors ensured we had a greater range of chromaticities (see Wilkins et al., 1992 for a discussion of the importance of chromaticity when choosing colored overlays).

### *Method*

#### *Participants*

16 children diagnosed with ASD (1 female), aged 7 - 15 years, and all attending schools for children with learning difficulties were compared to 16 typically developing (TD) children (3 females), aged 7 - 16 years and matched on performance IQ [PIQ; ASD: mean = 90.75 (14.26), TD: mean = 86.44 (13.78), ( $t(30)$ , .870,  $p=.40$ )], verbal IQ [VIQ; ASD: mean = 87.50 (17.03), TD: mean = 92.06 (12.32), ( $t(30)$ , -.868,  $p=.40$ )], full scale IQ [FSIQ; ASD: mean = 87.93 (16.39), TD: mean = 89.20 (12.45), ( $t(30)$ , -.243,  $p=.98$ )] and chronological age [CA; ASD: mean = 11;6 (2.74), TD: mean = 11;3 (2.38), ( $t(30)$ , .270,  $p=.28$ )]. All participants with ASD had a confirmed clinical diagnosis and scored above the ASD threshold on the Autism Diagnostic Observation Schedule –Generic (ADOS-G, 2000) (See Table 1). The Weschler Abbreviated Scale of Intelligence provided a measure of FSIQ (WASI; Wechsler, 1999) (See Table 1 for standardized scores). No participants had color vision deficiencies, as measured by the City University Color Vision test (3rd ed., Fletcher, 1998) and the Ishihara test (Ishihara, 1972). All participants had normal or corrected to normal vision (the benefit from tints is largely independent of routine optometric findings (Monger, Wilkins & Allen; in press). Ethical approval was obtained from the University of Essex ethics committee and informed consent was obtained from the parents of all participants.

### *Materials*

#### *Tint selection task*

To determine which colored tint best improved the clarity of text, two passages of identical text, 107mm wide by 60mm high, were presented in black 12-point Times font side by side with their inner margin 40mm from the center of a computer screen. The same 15 common words (come see the play look up is not for and my dog you to cat) appeared in a different random order on each of 10 lines, similarly for both passages. The text was black (unlit pixels) on a lit background that was either given a shade of colour or was gray. The lit background comprised the entirety of the screen. For the first 16 trials text was presented on two sides of the screen, and the background was colored one side of a vertical midline and gray on the other side, the side chosen at random. For the remaining trials the text was presented in the centre of the screen and the background was colored. The luminance of a surface is a photometric measure corresponding to the sensation of brightness and indicates how much light will be detected by an eye looking at the surface. The contrast between two surfaces is the difference in their luminance expressed as a proportion of the mean luminance of a reference surface, here the background surface. The superimposed colored tint reduced the contrast of the text on the background by less than 4%. Each background had one of the chromaticities shown by the inner ends of the lines in Figure 1. All the colored tints had an approximately equal saturation (strength of color, Commission Internationale de L'Eclairage: CIE 1976  $s_{uv}$ ) and were separated from neighboring colors by an approximately equal difference in hue (see Wilkins, 2003; 2012 for further information). Luminance contrast was measured for each of the tints in terms of Weber's contrast (see Whittle, 1994:  $\Delta L/L_b$ ).

#### *Wilkins Rate of Reading Test*

The Wilkins Rate of Reading Test (WRRT; Wilkins, et al., 1996) is a well-established speeded reading test, with four passages of text similar to that used in the tint selection task, and was tinted with the self-selected color (see above) or a gray.

#### *Emotional Intensity Discrimination*

Faces showing a range of facial expression were taken from a well-validated database (Montagne et al., 2006), which includes six emotional expressions at differing levels of intensity. Variation in intensity was achieved by morphing expressions with a neutral expression to yield 100%, 80% and 60% intensity expressions, for example: 100% happy, 80% happy+ 20% neutral, 60% happy + 40% neutral. This set of stimuli was preferred over other sets because expressions are morphed with a neutral face, rather than with another expression (e.g. 50% happy + 50%

angry, see Roberson et al., 2012). The grayscale face images were shown behind an oval aperture (height 133mm (600 pixels - major axis) width 112mm) in a gray mask, cropped of external features, such as hair and ears, with the oval shaped mask. Faces were presented in pairs side by side, with the center of the ovals on the horizontal midline of the screen and their inner margins separated by 21mm. Each oval subtended 23° high by 19° wide and both were covered by a tinted or gray transparent rectangular Photoshop object 275mm wide by 166mm high, on the 333mm by 210mm screen of a MacBook Pro, the remainder of which was gray (CIE 1976 u'v' chromaticity 0.230, 0.490). Both members of each pair of faces always displayed the same expression, which was either anger, disgust, fear, happiness, sadness or surprise, but one face displayed the expression at a lower emotional intensity than the other (see Figure 2). Forty-eight stimuli were presented twice each (colored and gray tint conditions), equally balanced across the six emotions. The face stimuli were both covered either by a gray or by the self-selected colored tint, as for the WRRT above. The Weber contrast for the face with a colored tint was lower than that for the same face with a gray tint. The chromaticities of the colored rectangles (measured from the tip of the nose) are shown in the outer circle of Figure 1. Therefore contrast was lower for colored tinted faces compared to gray tinted faces. The Weber contrast was measured at the tip of the nose of one face relative to the background and ranged across selected tint colors from 0.22 to 0.51 (average 0.38), less than for the gray tint (0.74).

*Chromaticities of colored and grey tints in the Tint selection task and Emotional Intensity Discrimination:*

The grey tint and 16 colored tints were created in Photoshop®. Corresponding RGB values, taken from the colors previously used in the Wilkins Rate of Reading Test, were used. Subsequent presentation of these tints in the Tint selection task and Wilkins Rate of Reading task were in Microsoft PowerPoint. Whereas presentation of tints in the Emotional Intensity Discrimination task was in Superlab®. As a result of the different software packages used chromaticities of the tints in the Wilkins Rate of Reading task and Emotional Intensity Discrimination task were slightly different (see Figure 1). As can be seen from the outer and inner points on Figure 1 saturation of each colored tint was different, with slightly greater saturation in the Emotional Intensity Discrimination task. However, points cluster together in the center, indicating that the hues of each tint in the two tasks are similar.

(Figure 1 top)



*Procedure**Tints selection task*

Participants viewed the screen from a distance of 0.4m, with line of sight to the center of the display perpendicular to the surface. Figure 1 gives details of the chromaticity measurements for all tints. For the first 16 trials, each of the 16 colors was randomly presented once on one side of the screen while the comparison gray tint was presented on the other side and participants were asked to choose which passage of text was clearest and most comfortable, without reading them. Each of the colors they shortlisted (between 1 and 14) was then paired with another shortlisted color so that by successive elimination the clearest/most comfortable color was ultimately selected. For this part of the tint selection procedure tints were presented consecutively.

*Choice of tint*

Participants were asked to decide, in the first 16 trials, which of two passages of text (one with gray tint one with colored tint) improved the clarity of text. Individuals with ASD and TD individuals showed similar variation in the number of colored tints chosen. Individuals chose between 1-to-14 colors as improving clarity, compared to the gray tint, [ASD: mean (SD):  $u'$ : 0.18 (0.02),  $v'$ : 0.48 (0.04), range: 1-14 different colored tints chosen, TD: mean (SD):  $u'$ : 0.17 (0.03),  $v'$ : 0.49 (0.02), range: 2-12 different colored tints chosen]. There was no systematic difference in the range or type of colours selected between groups.

(Figure 2 top)

*Wilkins Rate of Reading Test*

WRRT standard procedure was followed. The color finally selected was used to tint Passage 1 (99mm width x 50mm height) of the WRRT. The participant read the passage aloud as quickly and as accurately as possible for one minute, or until they finished the passage. Passage 2 was then presented with a gray tint (the same as used previously) and the reading repeated. Passages 3 and 4 followed, using the gray and colored tint respectively. The score was the number of words correctly read per minute, and words were counted as correct only if they were in the appropriate sequence. The average rate of reading (number of words per minute) for each condition was calculated.

*Emotional intensity discrimination task*

Participants were asked to decide which of a pair of faces on the screen had the strongest emotion. All participants successfully completed four practice trials for each condition, with feedback. The same instructions were given for the test phase, but without feedback. Order of face pairs was randomized and the task conditions were counterbalanced in two blocks (e.g. block 1: color tinted face pairs, block 2: gray tinted face pairs), separated by at least 2 hours to reduce practice effects. The participants' responses were made using a button box. The proportion of correct responses (out of 48) was calculated for each condition. The reaction time for each response was measured to the nearest millisecond.

*Results*

*WRRT* - Figure 3 shows the mean rate of reading speed on the WRRT for ASD and TD individuals with and without colored tints.

(Figure 3 top)

9/16 individuals with ASD had an improvement in the discrimination of the intensity of expressions of emotion of more than 5% with the colored tints, in contrast to 4/16 TD individuals. Significantly more individuals' with ASD than TD individuals showed an improvement of more than 5% ( $\chi^2(1, N=32) = 3.24, p = .036$ ).

Average WRRT scores were compared in a 2 (Group: ASD vs. TD) x 2 (Tints: colored vs. gray) mixed design ANOVA. It revealed no significant between-group differences in reading speed [ $F(1, 30) < 1$ ], but a significant effect of tint [ $F(1, 30) = 8.17, p = .008$ , partial  $\eta^2 = .21$ ]. More words were read per minute with a colored tint than with a gray tint. There was also a significant interaction [ $F(1, 30) = 6.97, p = .013$ , partial  $\eta^2 = .19$ ]. Simple main effects analysis revealed that the TD group's rate of reading did not differ between a colored or gray tint ( $p > .8$ ). However, individuals with ASD read significantly more words with a colored than a gray ( $p = .006$ ) (see Figure 3).

*Emotional intensity discrimination task*-Figure 4 depicts the results of the emotional intensity discrimination task for the ASD and TD groups.

(Figure 4 top)

A 2 (Group: ASD vs. TD) x 2 (Tints: colored vs. gray) mixed design ANOVA conducted on the proportion of correct responses found no significant main effect of group or tint. The ASD group's judgments of the intensity of

facial expressions did not differ to controls for gray or colored tints. There was a significant interaction [ $F(1, 30) = 5.703, p = .023$ , partial  $\eta^2 = .16$ ]. Only the ASD group were significantly more accurate with a colored tint than a gray one ( $p < .05$ ). There was no difference for the TD group (see Figure 4).

#### *Latency in the emotional intensity discrimination task*

The speed at which participants responded in the emotional intensity discrimination task were compared in a 2 (group) x 2 (Tints: colored vs. gray) mixed design ANOVA. There was no significant main effect of group [ $F(1, 30) p > .5$ ] or of tint [ $p > .09$ ]. There was no significant interaction between group and tint [ $p > .2$ ].

#### *Choice of tint*

To determine whether the difference in performance in the emotional intensity task was the result of differences in the contrast levels of tints chosen, the relative benefit of the tints in the emotional intensity task were compared to the contrast levels of the tints chosen by each group. Contrast level was calculated for each of the tints using Weber's contrast ( $\Delta L/L_b$ ). Contrast levels of the tints chosen by each group did not correlate with the relative benefit of the tints in the emotional intensity task in either group (ASD:  $r_s = -.33$ ;  $p > .2$ ; TD:  $r_s = -.10$ ;  $p > .7$ ). To determine whether the hue of the tints chosen by each group affected performance in the emotional intensity task, a median split grouped tints into the 8 coolest and 8 warmest colors. There was no difference in the number of instances in which both groups chose tints of cool and warm colors [ $\chi^2(1, N=32) = 2.133, p > .1$ ]: 9/16 children with ASD chose warm colors whereas the TD group's choices of cool and warm colors were equal.

#### *Correlations between social and communication ability and discrimination of the emotional intensity of faces*

The social ability and communication ability (ADOS-G, 2000) of children with ASD were not significantly correlated with the discrimination of gray tinted [social ability:  $r = .31, p = .23$ , communication ability:  $r = .26, p = .34$ ] or color tinted [social ability:  $r = .21, p = .43$ , communication ability:  $r = .42, p = .13$ ] faces. Neither was the improvement in discriminations of emotional intensity with a colored tint significantly correlated with social ability or communication ability (social ability:  $r = .004, p = .99$ , communication ability:  $r = .24, p = .37$ ).

#### *Correlations between the WRRT and emotional intensity discrimination task*

(Figure 5 top)

In the ASD group the improvement in performance with a tint on the WRRT was marginally correlated with improvement on the emotional intensity discrimination task ( $r = .41, p = .06$ ); 17% of the variance was accounted for by colored tints.

### *Discussion*

This study found that self-selected colored tints improved judgments of the intensity of facial expressions for individuals with ASD but not for TD individuals, in line with the findings of Ludlow et al. (2012). In contrast to TD individuals, whose judgments were (non-significantly) poorer when colored tints were added to faces, individuals with ASD showed a significant improvement in their judgments of the intensity of facial expressions. By displaying whole faces rather than single features, we demonstrate that the improvement is not restricted to the eyes (Ludlow et al., 2012), and may extend to judgments that involve some degree of configural or holistic processing (Calvo & Fernandez-Martin, 2013). Our task could be completed without accessing emotional labels, and in this respect differs from tasks used in previous studies. This improvement suggests that sensory abnormalities, such as visual stress, may relate to difficulties processing social stimuli, such as faces (Kliemann et al., 2010; Leekam, et al., 2000; Simmons et al., 2009).

However, the social and communication abilities of children with ASD, as assessed by the ADOS, did not correlate significantly with the discrimination of emotional intensity with a gray or colored tint nor with the improvement with color. Previously reported atypical attention to faces as well as a hypo- or hypersensitivity to faces (Hirstein et al., 2001; Hobson et al., 1988; Jones et al., 2008; Kylliainen & Hietanen, 2006; Langdell, 1978; Senju, 2007; Stagg, et al., 2013; Stagg et al., 2014; Yi et al., 2014) suggests that differences in visual processing may be stimulus specific. Future research could investigate visual processing of non-social objects to examine whether this effect is more pronounced for social stimuli.

The colored tints improved reading speed in the ASD group to an extent similar to that found by other studies (Ludlow et al., 2006; Ludlow et al., 2008). The improvement in reading rate and intensity discrimination supports the hypothesis that individuals with ASD experience visual stress that is not specific to social stimuli. A plausible neurological explanation for visual stress in ASD is a hyperexcitability of the cortex, suggested by the fact that migraine and ASD (Huang, et al., 2003) and epilepsy and ASD (Canitano, 2007; Tuchman & Cuccaro, 2011) tend

to co-occur. Wilkins (2003; 2012) has proposed a possible cortical mechanism whereby a colored overlay, chosen on an individual basis, may make a visual scene more comfortable to view.

The addition of a colored tint reduced the contrast of the face stimuli more than the gray tint but, this change in contrast was not correlated with performance (see also Jeanes et al., 1997; Wilkins et al., 2001). Moreover, improved intensity discrimination was not specific to any particular color. Nor was there a speed-accuracy trade-off because there were no differences in reaction times.

One important consideration is that the participants' perceived visual stress/ visual perceptual distortions were not quantified using a standardized measure. Therefore, it is unclear whether the perceived visual stress differed in children with ASD and TD controls. Previous research has highlighted that pattern glare; a visual perceptual distortion, and a correlate of Meares-Irlene syndrome, is reduced with colored overlays (Conlon et al., 1998; Evans, Patel & Wilkins, 2002; Evans et al. 1996; 2001; Wilkins & Neary, 1991). Future research could consider administering a standardized measure of visual perceptual distortions, such as the pattern glare test (I.O.O. Marketing Ltd, London, UK), which has previously been conducted in the field (Evans & Stevenson, 2008; Evans et al., 2002).

In conclusion, we have shown an improvement, with tints, in the discrimination of facial expressions using a two-alternative forced choice task without the use of emotional labels. The improvement occurred in the ASD group but not in controls. Our findings are consistent with the literature that suggests that abnormalities in sensory processing may in part account for impaired processing of faces (Behrmann et al., 2006; Greimel et al., 2014; Kliemann et al., 2010; Uljarevic & Hamilton, 2012). Furthermore, this pattern of performance speaks to previous research suggesting that atypical perceptual processing, of social and non-social information alike, may underpin differences in ASD face processing (Motttron et al., 2006a, 2006b).

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*Footnotes*

<sup>1</sup> Although participants may automatically access category labels even without specific instruction (see e.g. Roberson, et al., 1999; Roberson, et al., 2010; Roberson et al., 2012).

**Table 1: Mean (standard deviation in brackets) chronological age, verbal IQ (VIQ), performance IQ (PIQ), full-scale IQ (FSIQ) of all participants, and Autistic Diagnostic Observation Schedule scores for participants with ASD. IQ was assessed using the Weschler Abbreviated Scale of Intelligence (WASI) and are reported as standard scores**

	Age (years; months)	VIQ	PIQ	FSIQ	Autistic Diagnostic Observation Schedule		
					Communication	Social	Restrictive and Repetitive behaviours
ASD (n=16)	11;6 (2.74)	87.50 (17.01)	90.75 (14.26)	87.93 (16.39)	3.38 (1.67)	8.69 (2.39)	1.50 (1.03)
TD (n=16)	11;3 (2.38)	92.06 (12.32)	86.44 (13.78)	89.19 (12.49)	N/A	N/A	N/A

*Figures caption sheet*

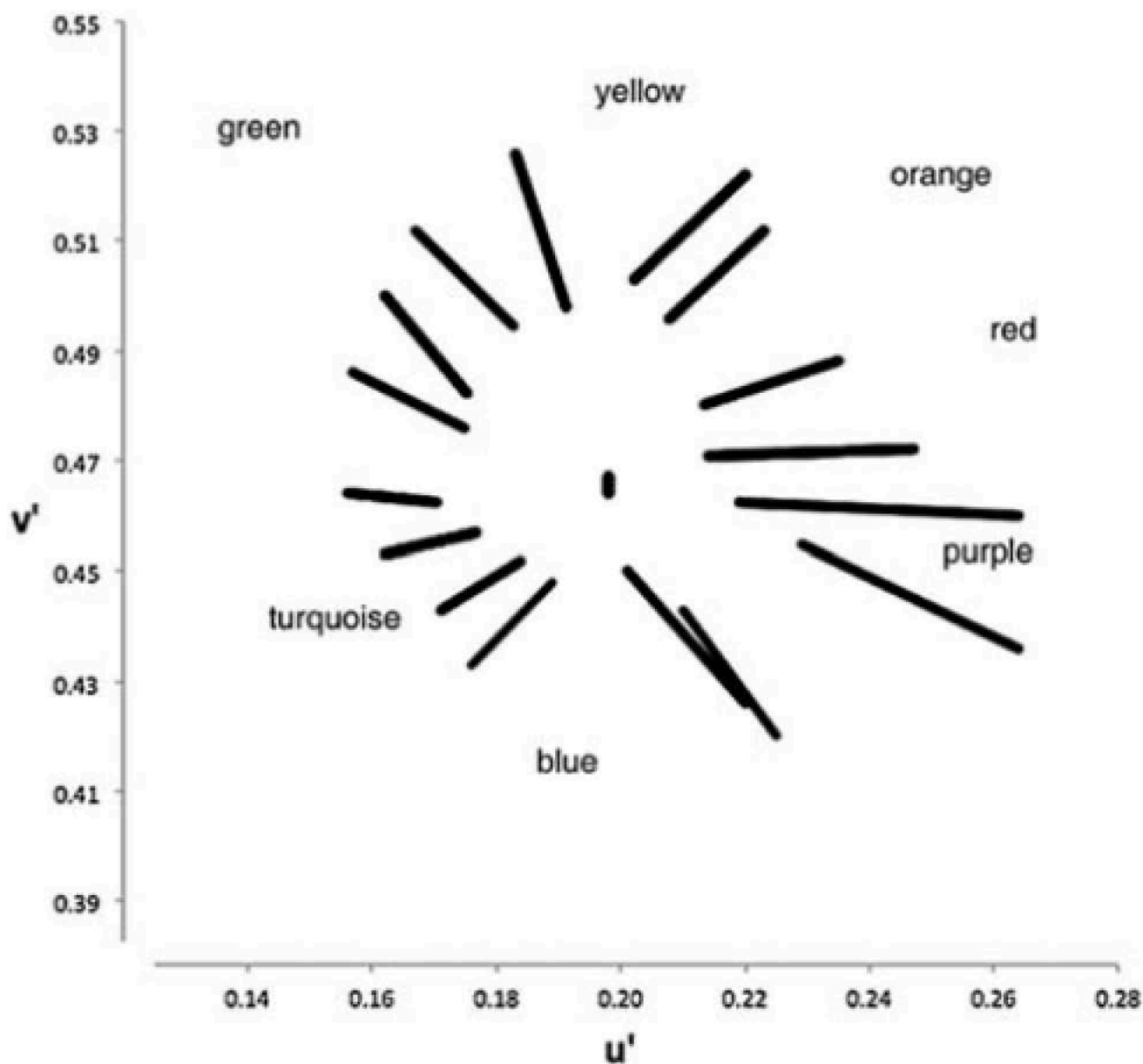
Figure 1. CIE Uniform chromaticity scale diagram showing the chromaticities of the tints. The chromaticities used in the tint selection task are shown by the inner ends of the lines. The outer ends show the chromaticities used in the emotion discrimination task. The lines connect similar hues. Verbal descriptions of the colors represented by the diagram are shown for reference. (For a description of  $u'$  and  $v'$  see Hunt & Pointer, 2011).

Figure 2. Emotional intensity discrimination task: Example of male stimuli expressing surprise at 60% vs. 80% (first pair) and 80% vs. 100% (second pair) in the gray tint condition.

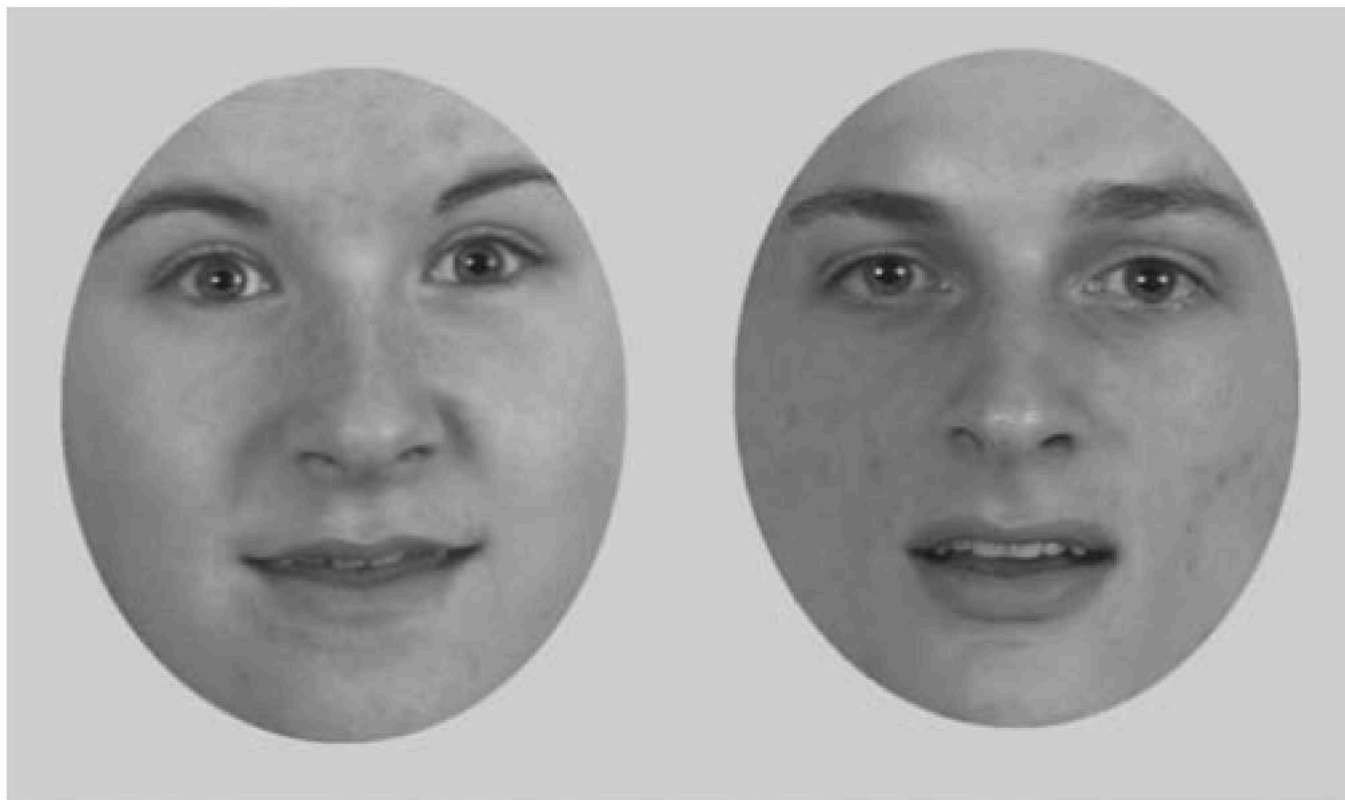
Figure 3. Average rate of reading (words per minute) for the ASD and TD groups

Figure 4. Proportion of correct face discriminations for the ASD and TD groups, averaged for all emotions.

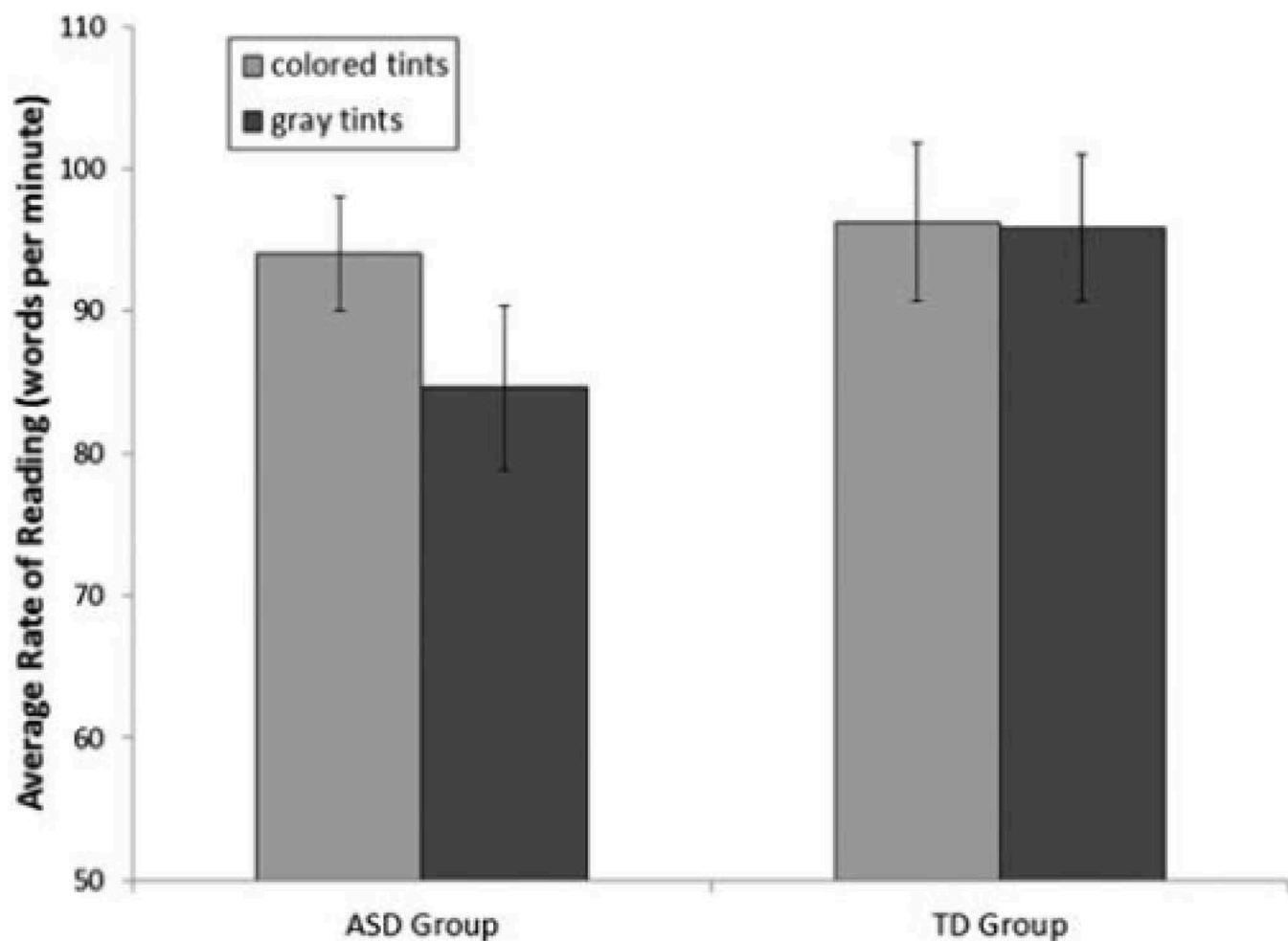
Figure 5. Improvements in performance with a tint in the WRRT as a function of the improvements in performance with a tint in the emotional intensity discrimination task for the ASD group.



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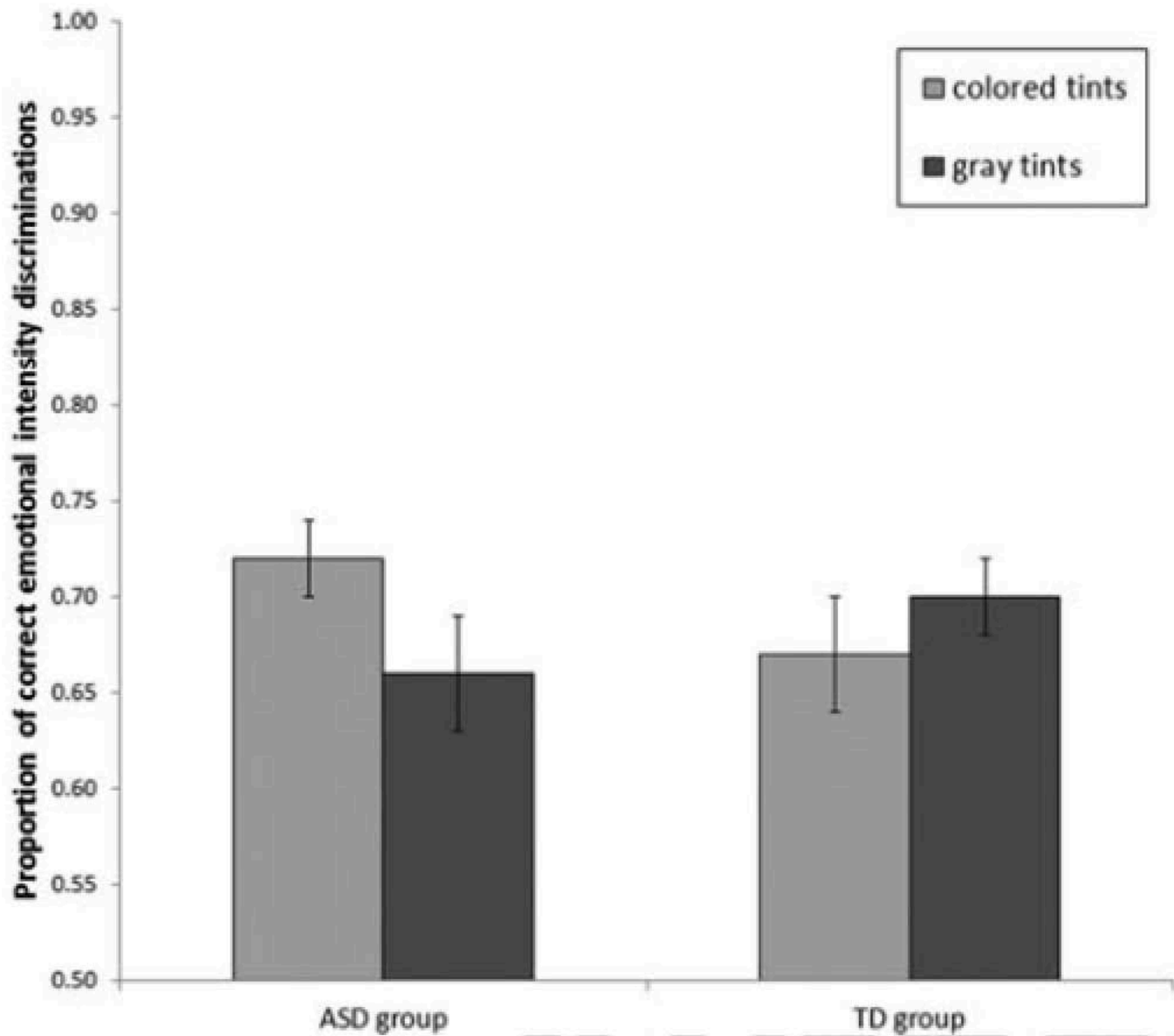


**Figure 2.** Emotional intensity discrimination task: example of male stimuli expressing surprise at 60% vs. 80% (first pair) and 80% vs. 100% (second pair) in the gray tint condition [Montagne et al., 2006].

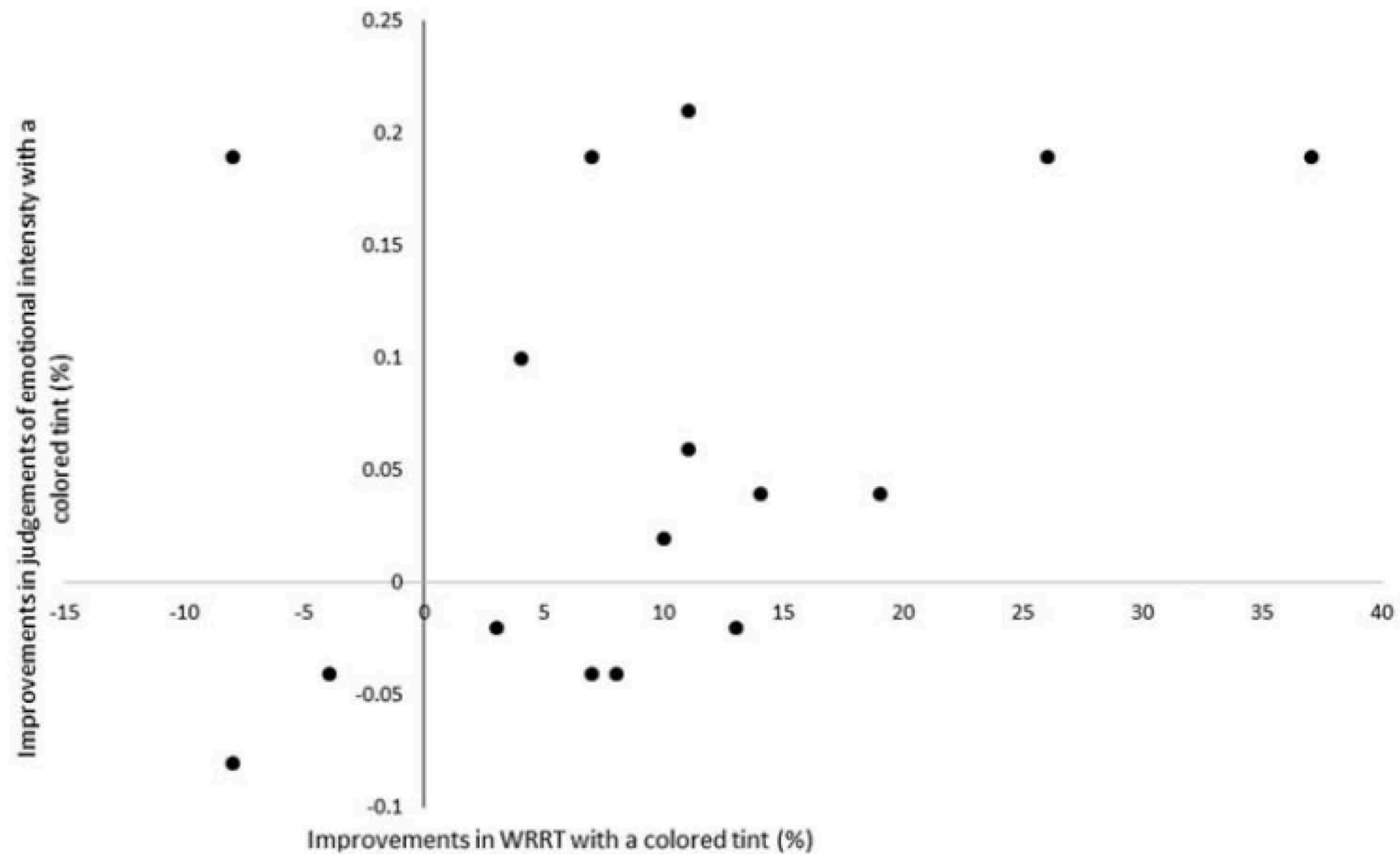


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